(84) Designated Contracting States:
DE FR GB

(30) Priority: 14.08.1995 JP 207108/95

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(54)   **A method for purifying exhaust gas of a diesel engine**

(57)   According to the method of the present invention, NO (nitrogen monoxide) in the exhaust gas of a diesel engine is first oxidized to NO_2 (nitrogen dioxide) by an oxidizing catalyst (5). Further, carbon particles in the exhaust gas are trapped by a DPF (7) (diesel particulate filter). The exhaust gas containing NO_2 formed by oxidation of nitrogen monoxide is, then, fed to the DPF (7), and NO_2 in the exhaust gas reacts with the carbon particles trapped in the DPF (7). When the NO_2 reacts with carbon particles, carbon particles are oxidized (burned) by NO_2 and removed from DPF (7), and, at the same time, NO_2 is reduced to NO by the carbon particles. The exhaust gas containing NO formed by the reaction between the carbon particles and NO_2 is fed to an NO_X absorbent (9). In the NO_X absorbent (9), NO is absorbed by the NO_X absorbent (9) and, thereby, removed from the exhaust gas. Therefore, according this method, the carbon particles collected by the DPF (7) can be easily burned by NO_2, thereby being removed from the DPF (7) without increasing the amount of NO released to the atmosphere.
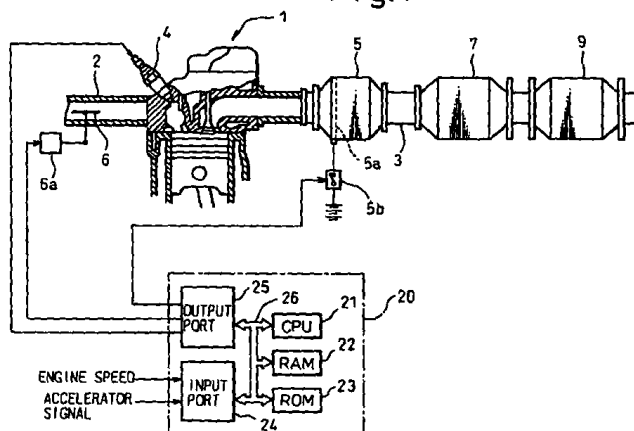
Fig.1

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method for purifying the exhaust gas of a diesel engine. More specifically, the present invention relates to a method for purifying the exhaust gas of a diesel engine which is capable of removing both carbon particles and nitrogen oxide contained in the exhaust gas.

### 2. Description of the Related Art

A method for removing carbon particles (i.e., soot) from the exhaust gas of a diesel engine is disclosed in, for example, Japanese Unexamined Patent Publication (Kokai) No. 1-318715.

In the '715 publication, an oxidizing catalyst and a DPF (diesel particulate filter) are disposed in the exhaust gas passage of a diesel engine, from the upstream side, in this order. The DPF is a filter for collecting and removing diesel particulates which mainly consist of carbon particles (i.e., soot) from the exhaust gas. In the '715 publication, NO (nitrogen monoxide) in the exhaust gas of the diesel engine is oxidized by the oxidizing catalyst and forms NO_2 (nitrogen dioxide) in the exhaust gas. Therefore, exhaust gas containing NO_2 flows into the DPF. This NO_2 reacts with the carbon particles trapped in the DPF and, thereby, the carbon particles are burned and removed from the DPF. Therefore, the carbon particles are not accumulated in the DPF.

Heretofore, it is considered that a temperature higher than a normal exhaust gas temperature is required for burning the carbon particles trapped in the DPF. However, the method in the '715 publication makes it possible to burn the carbon particles in the DPF at a temperature available in the normal operation of the engine (for example, less than 300°C) by reacting NO_2 in the exhaust gas with the carbon particles in the DPF. Therefore, no heating means such as an electric heater is required for heating the DPF in order to initiate combustion of the carbon particles. Thus, according to the method in the '715 publication, the carbon particles can be removed from the exhaust gas by a simple device.

However, though the method in the '715 publication can remove the diesel particulates in the exhaust gas, it cannot prevent nitrogen oxide in the exhaust gas from being released into the atmosphere.
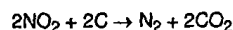
In the method in the '715 publication, NO_2 in the exhaust gas burns the diesel particulates consisting of carbon particles by the reactions

$$NO_2 + C \rightarrow NO + CO$$

and,

$$2NO_2 + 2C \rightarrow N_2 + 2CO_2$$
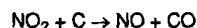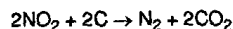
. However, it was found that the reaction

$$2NO_2 + 2C \rightarrow N_2 + 2CO_2$$

hardly occurs at a relatively low temperature (such as an exhaust gas temperature available in the normal operation of the diesel engine). Therefore, if the method in the '715 publication is applied to a diesel engine, a major portion of NO_2 in the exhaust gas flowing into the DPF is converted to NO by the reaction

$$NO_2 + C \rightarrow NO + CO$$
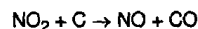
and, thereby, the amount of NO in the exhaust gas released to the atmosphere increases.

Further, since diesel fuel contains a relatively large amount of sulfur, SO_2 (Sulfur dioxide) is contained in the exhaust gas of a diesel engine. Therefore, if an oxidizing catalyst is used for oxidizing NO to NO_2 in the exhaust gas as in the method in the '715 publication, SO_2 in the exhaust gas is also oxidized by the oxidizing catalyst and forms sulfate (SO_3) in the exhaust gas. The sulfate in the exhaust gas is not collected by the DPF and is released to the atmosphere. Further, since sulfate is detected as particulate matter, the amount of the diesel particulates released to the atmosphere increases due to sulfate formed by the oxidizing catalyst if the method in the '715 publication is applied to the diesel engine.

SUMMARY OF THE INVENTION

In view of the problems in the related art as set forth above, the object of the present invention is to provide a method for purifying the exhaust gas of a diesel engine which is capable of easily removing the diesel particulates collected by the DPF without increasing the amounts of nitrogen oxide and sulfate released to the atmosphere.

This object is achieved by a method, for purifying the exhaust gas of a diesel engine, in which the method comprises a step for oxidizing nitrogen monoxide in the exhaust gas of a diesel engine into nitrogen dioxide, thereby forming nitrogen dioxide in the exhaust gas, a step for collecting carbon particles contained in the exhaust gas, a step for reacting nitrogen dioxide in the exhaust gas formed by oxidation of nitrogen monoxide with the collected carbon particles, thereby oxidizing the collected carbon particles by nitrogen dioxide in the exhaust gas and, at the same time, reducing nitrogen dioxide in exhaust gas to nitrogen monoxide, and a step for removing nitrogen monoxide formed by the reaction between nitrogen dioxide and the collected carbon particles from the exhaust gas.

According to the present invention, diesel particulates in the exhaust gas of a diesel engine which is mainly consist of carbon particles is collected, for example, by a DPF. Nitrogen dioxide formed by the oxidation

of nitrogen monoxide reacts with the collected carbon particles, and the carbon particles are oxidized (i.e., burned) at a relatively low temperature. When nitrogen dioxide and the collected carbon particles react each other, carbon particles are oxidized to carbon monoxide or carbon dioxide and, at the same time, nitrogen dioxide is reconverted to carbon monoxide and nitrogen monoxide, respectively. In this embodiment, this nitrogen monoxide is removed from the exhaust gas in the final step. Therefore, nitrogen monoxide is not released to the atmosphere.

According to one aspect of the present invention, nitrogen monoxide generated by the reaction between nitrogen dioxide and the carbon particles is collected by, for example, NO_X absorbent which absorbs nitrogen oxide in the exhaust gas. Further, according to another aspect of the present invention, nitrogen monoxide generated by the reaction between nitrogen dioxide and the carbon particles are reduced to nitrogen by, for example, an NO_X reducing catalyst which has a capability for selectively reducing nitrogen oxide in the exhaust gas even in an oxidizing atmosphere.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood from the description as set forth hereinafter, with reference to the accompanying drawings in which:

Fig. 1 schematically illustrates an embodiment of a device for conducting the method in the present invention when applied to an automobile diesel engine;
Fig. 2 is a flowchart illustrating a regenerating operation of the DPF and the NO_X absorbent in the embodiment in Fig. 1;
Fig. 3 is a flowchart illustrating a determination of conditions for carrying out the regenerating operation in Fig. 2;
Fig. 4 is a flowchart illustrating a setting operation of the values of counters used in the flowchart in Fig. 3;
Fig. 5 is a timing diagram illustrating timing for regeneration of the DPF and the NO_X absorbent;
Fig. 6 is a drawing similar to Fig. 1 which illustrates another embodiment of a device for conducting the method in the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Fig. 1 shows an embodiment of an exhaust gas purification device which utilizes the method of the present invention.

In Fig. 1, reference numeral 1 designates a diesel engine for an automobile. Though a multiple cylinder diesel engine is used in this embodiment, Fig. 1 shows one cylinder only. Numerals 2 and 3 designate an intake air passage and an exhaust gas passage, respectively. A fuel injection valve 4, which injects pressurized fuel into a combustion chamber, is provided on each of the cylinders.

In this embodiment, an intake shutter valve 6 is disposed in the intake air passage 2. The intake shutter valve 6 is a type, such as a butterfly valve, which generates low flow resistance when open, and is used for throttling the intake air passage 2 to reduce the amount of intake air during the regenerating operation of the DPF. By reducing the amount of intake air, temperature of the exhaust gas becomes high, and combustion of the carbon particles in the DPF is facilitated. In Fig. 1, the numeral 6a is an actuator of appropriate type, such as a vacuum actuator or solenoid actuator, which opens and closes the intake shutter valve 6 in accordance with a control signal supplied by a control circuit 20.

In the exhaust gas passage 3, an oxidizing catalyst 5 for oxidizing NO (nitrogen monoxide) in the exhaust gas to NO_2 (nitrogen dioxide), a DPF (diesel particulate filter) 7 for collecting the diesel particulates in the exhaust gas and an NO_X absorbent 9 for collecting (absorbing) NO_X (nitrogen oxide) in the exhaust gas are disposed in this order from the upstream end. The oxidizing catalyst 5, the DPF 7 and the NO_X absorbent 9 are explained later in detail.

The control circuit 20 may consist of, for example, a microcomputer of a known type and comprises a CPU (a microprocessor) 21, a RAM (a random access memory) 22, a ROM (read-only memory) 23, an input port 24 and an output port 25 all connected each other by a bi-directional bus 26. The control circuit 20 performs the basic control of the engine 1 such as fuel injection control. In this embodiment, the control circuit 20 further performs regeneration control of the DPF 7 and NO_X absorbent 9. In this embodiment, as explained later, an operation for burning the carbon particles (diesel particulate) collected in the DPF 7 is referred to as "a regeneration of the DPF", and an operation for causing NO_X absorbent to release the absorbed NO_X is referred to as "a regeneration of the NO_X absorbent".

In order to perform these types of control, an engine speed signal and an accelerator signal are supplied to the input port 24 of the control circuit 20 from the respective sensors not shown in the drawing. Further, the output port 25 is connected to the fuel injection valve 4 of the engine 1 and the actuator 6a of the intake shutter valve 6, respectively, via the respective drive circuits not shown in the drawing, in order to control the amount and timing of fuel injection and the operation of the intake shutter valve 6.

The oxidizing catalyst 5 uses, for example, a honeycomb type substrate made of cordierite. On this substrate, an alumina layer which acts as a carrier of the catalytic components is applied. In this embodiment, catalytic components of precious metals such as platinum (Pt) or palladium (Pd) are attached to the alumina carrier. The oxidizing catalyst 5 oxidizes HC and CO in the exhaust gas when the air-fuel ratio of the exhaust gas is lean. Further, the oxidizing catalyst 5 oxidizes NO in the exhaust gas and converts it to NO_2. In this

embodiment, the term "air-fuel ratio of the exhaust gas" means a ratio of the amounts of air and fuel supplied to the engine and at portions upstream of a considered point in the exhaust system. Therefore, when no secondary air or additional fuel are supplied to the exhaust passage, the air-fuel ratio of the exhaust gas agrees with an operating air-fuel ratio of the engine (i.e., an air-fuel ratio of the air-fuel mixture in the combustion chambers of the engine 1).

Further, in this embodiment, an electric heater 5a is disposed on an upstream side end of the oxidizing catalyst 5. The electric heater 5a is activated in a condition in which the exhaust gas temperature is low, such as at cold start of the engine, to heat the oxidizing catalyst 5 to the activating temperature of the catalyst. The activation of the electric heater 5a is controlled by a control signal from the control circuit 20 supplied to a relay 5b of the electric heater 5a. As explained later, the electric heater 5a is also used in conjunction with the intake shutter valve 6 to raise the exhaust gas temperature when regenerating operation of the DPF 7 is conducted.

DPF 7 is a honeycomb type porous filter made of, for example, cordierite. In the DPF 7, numerous exhaust gas passages are formed in parallel. Approximately half of the exhaust gas passages are plugged at the upstream ends thereof, and the rest of the passages are plugged at the downstream ends thereof. The exhaust gas passages plugged at the upstream ends and the exhaust gas passages plugged at the downstream ends are disposed in the DPF 7 alternately. The exhaust gas of the engine flows into the DPF 7 through the passages having open upstream ends, and flows into the exhaust gas passages having open downstream ends through porous walls separating the exhaust gas passages from each other, and flows out from the DPF 7 through the passages having open downstream ends. Therefore, particles such as the carbon particles are collected by the porous walls of the DPF 7. In this embodiment, the carbon particles collected by the DPF 7 are burned by NO_2 in the exhaust gas as explained later. Therefore, to facilitate combustion of the collected carbon particles, oxidizing catalyst such as platinum (Pt) is attached to alumina coating formed on the porous wall.

The NO_X absorbent 9 in this embodiment uses, for example, a honeycomb type substrate made of cordierite. On this substrate, an alumina layer which acts as a carrier of the catalytic components is applied. On this carrier, precious metals such as platinum (Pt) rhodium (Rh), and at least one substance selected from alkali metals such as potassium (K), sodium (Na), lithium (Li) and cesium (Cs); alkali-earth metals such as barium (Ba) and calcium (Ca); and rare-earth metals such as lanthanum (La) and yttrium (Y) is carried. The NO_X absorbent 9 absorbs NO_X (nitrogen oxide) in the exhaust gas when the air-fuel ratio of the exhaust gas is lean, and releases the absorbed NO_X when the oxygen concentration of the exhaust gas flowing the NO_X absorbent becomes lower.

Though the mechanism of this absorbing and

releasing operation of the NO_X absorbent is not clear at present, it is thought that the absorbing and releasing operation is conducted by the following mechanism. Though the following mechanism of the absorbing and releasing operation of the NO_X absorbent is explained for the case where platinum Pt and barium Ba are carried on the carrier, as an example, it is thought that a similar mechanism also applies even if other precious metal, alkali metals, alkali earth metals, or rare earth metals are used.

Namely, when the concentration of O_2 in the exhaust gas increases, i.e., exhaust gas becomes lean, the oxygen O_2 in the exhaust gas is deposited on the surface of platinum Pt in the form of O_2^- or O^{2-}. The NO in the exhaust gas reacts with O_2^- or O^{2-} on the surface of the platinum Pt and becomes NO_2 by the reaction

$$2NO + O_2 \rightarrow 2NO_2.$$
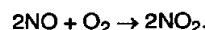
Then, NO_2 in the exhaust gas and the NO_2 produced on the platinum Pt are further oxidized on the surface of platinum Pt and absorbed into the NO_X absorbent while bonding with the barium oxide BaO and diffusing in the absorbent in the form of nitric acid ions NO_3^-. Thus, NO_X in the exhaust gas is absorbed by the NO_X. absorbent 9 when the air-fuel ratio of the exhaust gas is lean.

On the other hand, when the oxygen concentration in the exhaust gas becomes low, i.e., when the air-fuel ratio of the exhaust gas becomes stoichiometric or rich, the production of NO_2 on the surface of the platinum Pt is lowered and the reaction proceeds in an inverse direction

$$(NO_3^- \rightarrow NO_2)$$
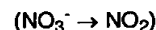
, and thus nitric acid ions NO_3^- in the absorbent are released in the form of NO_2 from the NO_X absorbent 9.

In this case, if a reducing substance such as CO, or a substance such as HC and CO_2 exist in the exhaust gas, released NO_X is reduced on the platinum Pt by these components. Namely, the NO_X absorbent 9 performs the absorbing and releasing operation of the NO_X in the exhaust gas in which the NO_X in the exhaust gas is absorbed by the NO_X absorbent when the air-fuel ratio of the exhaust gas is lean and, released from the NO_X absorbent and reduced to N_2 when the air-fuel ratio of the exhaust gas becomes stoichiometric or rich.

Since a diesel engine is used in this embodiment, the air-fuel ratio of the exhaust gas in a normal operation is considerably lean compared to the stoichiometric air-fuel ratio (for example, an air-fuel ratio of about 30). Further, the exhaust gas at the outlet of a diesel engine contains a small amount of NO_X (mainly NO) and a relatively large amount of the diesel particulates (carbon particles). This exhaust gas is first supplied to the oxidizing catalyst 5, and NO in the exhaust gas is oxidized to NO_2 by the reaction

$$2NO + O_2 \rightarrow 2NO_2$$
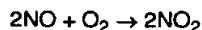
. Thus, NO in the exhaust gas is converted to NO_2 by the oxidizing catalyst 5.

The exhaust gas containing NO_2, then, flows into the DPF 7, where the carbon particles in the exhaust gas are collected by the DPF 7. A portion of the carbon particles collected by DPF 7 reacts with NO_2 in the exhaust gas, and generates NO and CO by the reaction
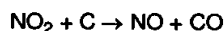
$$NO_2 + C \rightarrow NO + CO$$
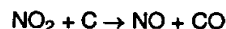
as explained before.

However, since the amount of NO emitted from the engine in the normal operation of the diesel engine is smaller compared to the amount of carbon particles, and since the temperature of the exhaust gas in a normal operation of the engine is low (for example, about 200°C), the reaction

$$NO_2 + C \rightarrow NO + CO$$

is not very likely to occur in the normal operation of the engine. Therefore, collected carbon particles gradually accumulate in the DPF 7. Further, the exhaust gas flowing out from the DPF 7 contains NO_2 which did not react with the carbon particles and NO generated by the above-explained reaction.

This exhaust gas, then, flows into the NO_X absorbent 9. Since the air-fuel ratio of the exhaust gas of the diesel engine 1 is lean in the normal operation, NO and NO_2 in the exhaust gas are absorbed by the NO_X absorbent 9 as explained before, and removed from the exhaust gas. Therefore, the exhaust gas flowing out from the NO_X absorbent 9 is practically free from NO_X and the carbon particles.

Though the carbon particles and NO_X are removed from the exhaust gas by the DPF 7 and NO_X absorbent 9, respectively, the carbon particles and NO_X gradually accumulate in the DPF 7 and NO_X absorbent 9. When the carbon particles accumulate in the DPF 7, a pressure drop through the DPF 7 increases, and the engine output is lowered due to an increase in the exhaust back pressure. Further, when an amount of NO_X accumulates in the NO_X absorbent 9, the capability of the NO_X absorbent 9 for absorbing NO_X in the exhaust gas becomes lower, and a portion of NO_X in the exhaust gas is released to the atmosphere without being absorbed by the NO_X absorbent 9.

In order to prevent these problems, the DPF 7 and NO_X absorbent 9 are regenerated periodically in this embodiment. In the regenerating operation of the DPF 7, the carbon particles accumulated in the DPF are burned, and removed from the DPF 7, thereby, the pressure drop through the DPF 7 is reduced to a normal value. In the regenerating operation of the NO_X absorbent 9, NO_X absorbed by the NO_X absorbent is released and, at the same time, reduced to N_2, therefore, the NO_X absorbing capability is resumed.

Next, the regenerating operations of the DPF 7 and NO_X absorbent 9 are explained.

In this embodiment, the regeneration of the NO_X absorbent 9 is conducted by shifting the air-fuel ratio of the exhaust gas to a rich air-fuel ratio side compared to the stoichiometric air-fuel ratio for a short period. When the air-fuel ratio of the exhaust gas becomes rich, the concentration of O_2 in the exhaust gas becomes lower, and the concentration of HC and CO in the exhaust gas becomes higher. Since the air-fuel ratio of the exhaust gas is rich, oxidation of HC and CO does not occur in the oxidizing catalyst 5. Therefore, most of HC and CO in the exhaust gas passes through the oxidizing catalyst 5 and the DPF 7, and the exhaust gas containing a relatively small amount of O_2 and a relatively large amount of HC and CO flows into the NO_X absorbent 9. When this exhaust gas flows into the NO_X absorbent 9, NO_X is released from the NO_X absorbent 9 and reduced by HC and CO in the exhaust gas, i.e., the NO_X absorbent 9 is regenerated.

In this embodiment, the air-fuel ratio of the exhaust gas is enriched by injecting fuel from the fuel injection valve 4 two times in every cycle of each cylinder. In the normal operation of the engine, the fuel injection amount TAU is determined by the control circuit 20 in accordance with the accelerator signal (i.e., the amount of depression of the accelerator pedal) and the engine speed based on a predetermined relationship. This amount of fuel is injected into each cylinder at a later stage in the compression cycle. In the normal operation, the fuel injection amount TAU is determined so that the air-fuel ratio of the engine becomes considerably lean (about an air-fuel ratio of 30). It may be possible to make the engine operating air-fuel ratio rich by increasing the amount of fuel injected in the compression cycle. However, if the amount of fuel injected in the compression cycle is increased, the engine output torque also increases by the amount corresponding to the increased fuel and, thereby, problems such as a torque shock or a reduction in the service lives of parts of the engine will occur.

Therefore, in this embodiment, the engine operating air-fuel ratio is enriched by injecting fuel from the fuel injection valve 4 in the exhaust cycle of each cylinder in addition to the normal fuel injection at a later stage of the compression cycle. When fuel is injected in the exhaust cycle, only a small amount of fuel is burned, and the engine output torque does not increase. Further, most of the injected fuel is vaporized in the cylinder and discharged from the engine with the exhaust gas. This fuel is decomposed by the oxidizing catalyst 5 and generates a large amount of HC and CO in the exhaust gas. Therefore, since the exhaust gas flowing into the NO_X absorbent 9 contains a large amount of HC and CO, and a small amount Of O_2, the NO_X absorbent 9 is regenerated in a short time.

The amount of NO_X released from the NO_X absorbent 9 becomes larger as the degree of richness of the exhaust gas becomes higher (i.e. , the air-fuel ratio of

the exhaust gas becomes lower). Therefore, the time required for regenerating the NO_X absorbent 9 becomes shorter as the degree of richness of the exhaust gas becomes higher. Further, the time required for regenerating the NO_X absorbent 9 becomes shorter as the amount of NO_X absorbed in the NO_X absorbent is smaller. Therefore, in this embodiment, the regenerating operation of the NO_X absorbent 9 is conducted at intervals of between ten seconds to several minutes, and the air-fuel ratio of the exhaust gas is maintained at about 13 (a rich air-fuel ratio) for about 0.5 seconds during the regenerating operation.

Next, the regenerating operation of the DPF 7 is explained. As explained before, the carbon particles collected in the DPF 7 are burned by reaction with the NO_2 in the exhaust gas in this embodiment. Further, NO generated by the reaction between the carbon particles and NO_2 is absorbed by the NO_X absorbent 9 disposed downstream of the DPF 7. Therefore, it is necessary that the air-fuel ratio of the exhaust gas during the regenerating operation of the DPF 7 is lean. Further, it is preferable to maintain the exhaust gas at a high temperature in order to promote the combustion of the carbon particles. Therefore, the additional fuel injection during the exhaust cycle is also performed during the regenerating operation of the DPF 7 in order to raise the exhaust gas temperature. The amount of fuel injected during the exhaust cycle is determined so that the air-fuel ratio of the exhaust gas stays lean compared to the stoichiometric air-fuel ratio. As explained before, most of the fuel injected during the exhaust cycle is discharged from the cylinder without being burned, and this fuel is decomposed (oxidized) by the oxidizing catalyst 5. Therefore, the exhaust gas is heated by the oxidation of the fuel. In this embodiment, in order to raise the exhaust gas temperature further, the intake shutter valve 6 is closed to a predetermined degree of opening and the electric heater 5a is activated during the regenerating operation of the DPF 7. Since the amount of intake air is reduced by the intake shutter valve 6, the temperature of the exhaust gas of the engine becomes higher than the temperature in the normal operation of the engine. Further, since the exhaust gas is heated by the electric heater 5a and the combustion of fuel on the oxidizing catalyst 5, high temperature exhaust gas (for example, 400 to 500°C) flows into the DPF 7. Therefore, the carbon particles accumulated in the DPF 7 easily react with NO_2 in the exhaust gas. Thus, the carbon particles in the DPF 7 are burned and removed from the DPF 7. Further, since the air-fuel ratio of the exhaust gas passing through the DPF 7 is still lean, NO in the exhaust gas generated by the reaction between the carbon particles and NO_2 emitted from the diesel engine are absorbed by the NO_X absorbent 9, and NO_X (nitrogen oxide) is not released into the atmosphere during the regenerating operation of the DPF 7. In this embodiment, the regenerating operation of the DPF 7 is conducted at intervals of between ten minutes to several hours. The regeneration of the DPF 7 is accomplished

in several minutes, and the air-fuel ratio of the exhaust gas is maintained at about 20 (a lean air-fuel ratio) during the regenerating operation.

The regenerating operation of the NO_X absorbent 9 is conducted at intervals of between ten seconds to several minutes as explained before. Therefore, the regenerating operation of the NO_X absorbent 9 is also conducted during the regenerating operation of the DPF 7. In this case, the amount of the fuel is increased so that the air-fuel ratio of the exhaust gas becomes rich (an air-fuel ratio of about 13) with the intake shutter valve 6 being closed. Therefore, when the regenerating operation of the NO_X absorbent 9 is conducted during the regenerating operation of the DPF 7, the NO_X absorbent 9 is regenerated by the exhaust gas having a higher temperature than that during the normal regenerating operation. The reason why the regenerating operation of the NO_X absorbent 9 is performed even during the regenerating operation of the DPF 7 is explained hereinafter.

The exhaust gas of the diesel engine 1 contains a relatively large amount of SO_2 (sulfur dioxide) generated by combustion of sulfur in diesel fuel. SO_2 in the exhaust gas is oxidized to SO_3 (sulfate) by the oxidizing catalyst 5 during the operation of the engine 1. SO_3 is not collected by the DPF 7 and is released to the atmosphere. Further, since SO_3 is detected as particulate matter, if an oxidizing catalyst is disposed in the exhaust gas passage of a diesel engine, the amount of the diesel particulates released to the atmosphere increases.

However, in this embodiment, the NO_X absorbent 9 is disposed in the exhaust gas passage downstream of the DPF 7. SO_3 in the exhaust gas is also absorbed by the NO_X absorbent 9 by the mechanism same as the absorption of NO_X, and held in the NO_X absorbent 9 in the form of sulfate such as $BaSO_4$. Therefore, SO_3 formed by the oxidizing catalyst 5 and passing through the DPF 7 is absorbed (collected) by the NO_X absorbent 9 in this embodiment. Namely, sulfate SO_3 in the exhaust gas, as well as NO generated by the combustion of the carbon particles, is removed from the exhaust gas by the NO_X absorbent 9.

SO_3 absorbed in the NO_X absorbent 9 is also released when the air-fuel ratio of the exhaust gas becomes rich by the same mechanism as that which releases NO_X. However, since the sulfate formed in the NO_X absorbent is more stable than the nitrate formed by NO_X, a temperature higher than the normal regenerating operation of the NO_X absorbent is required to release sulfate from the absorbent. Therefore, if the normal regenerating operation in which only the air-fuel ratio of the exhaust gas is enriched is conducted, sulfate is not release from the absorbent. This causes accumulation of the SO_3 in the NO_X absorbent 9, and eventually, causes saturation of NO_X absorbent 9 with SO_3. If the saturation of NO_X absorbent 9 with the absorbed SO_3 occurs, the absorbing capacity of the NO_X absorbent for both SO_3 and NO_X decreases largely. Therefore, the NO_X absorbent 9 is regenerated at a exhaust gas

temperature higher than that in the normal regenerating operation during the regenerating operation of the DPF 7 to release sulfate, as well as NO_X, from the NO_X absorbent 9. By regenerating the NO_X absorbent 9 at a high exhaust gas temperature, SO_3 absorbed in the absorbent is released in the form of SO_2 and thereby, the absorbing capability of the NO_X absorbent 9 is maintained.

Next, actual regenerating operations of the DPF 7 and NO_X absorbent 9 are explained with reference to Figs. 2 through 4.

Figs. 2 through 4 are flowcharts explaining embodiments of routines performed by the control circuit 20 for controlling regenerating operations of the DPF 7 and NO_X absorbent 9.

Fig. 2 is a routine for conducting the regenerating operations of the DPF 7 and NO_X absorbent 9. This routine is performed at regular intervals. In Fig. 2, at step 201, it is determined whether a value of a flag ADPF is set to 1. ADPF is a regenerating flag of the DPF 7, and the value thereof is set to 1 by the routine in Fig. 3 when the conditions for conducting the regenerating operation of the DPF 7 are satisfied. If ADPF = 1 at step 201, since the regenerating operation of the DPF 7 is required, the routine executes step 203 to close the intake shutter valve 6 to a predetermined degree of opening and to activate the electric heater 5a of the oxidizing catalyst 5. After executing step 203, the routine determines at step 205 whether the value of a flag ANOX is set to 1. ANOX is a regenerating flag of the NO_X absorbent 9. Similarly to the flag ADPF, the value of the flag ANOX is set to 1 in the routine in Fig. 3 when the conditions for conducting the regenerating operation of the NO_X absorbent 9 are satisfied.

If ANOX ≠ 1 at step 205, i.e., if only the conditions for conducting the regenerating operation of the DPF 7 are satisfied, and the conditions for conducting the regenerating operation of the NO_X absorbent 9 are not satisfied, the routine proceeds to step 207 to calculate the required additional fuel injection amount TAU21 in accordance with the engine speed and the accelerator signal (i.e., the amount of depression of the accelerator pedal). The additional fuel injection amount TAU21 represents the amount of fuel injected during the exhaust cycle of each cylinder in addition to the normal fuel injection during the compression cycle. TAU21 is determined in such a manner that the air-fuel ratio of the exhaust gas becomes a predetermined lean value (for example, about 20). More specifically, at step 207, an intake air amount Q is determined in accordance with the degree of opening of the intake shutter valve 6 and the engine speed, and the normal fuel injection amount TAU is determined in accordance with the engine speed and the accelerator signal, then the value of TAU21 is determined in accordance with Q and TAU so that the air-fuel ratio of the exhaust gas becomes a predetermined lean value (about 20) by the total amount (TAU + TAU21) of fuel injection.

At step 209, the value of the actual fuel injection amount TAU2 of the additional exhaust cycle fuel injection is set to the value TAU21 calculated at step 207.

When the value of TAU2 is set to TAU21, an amount TAU21 of fuel is injected to each cylinder during its exhaust cycle by a fuel injection routine (not shown) processed by the control circuit 20, and a total amount TAU + TAU21 of fuel is supplied to each cylinder in a cycle. Thus, the air-fuel ratio of the exhaust gas discharged from the cylinders becomes a lean value of about 20.

In this case, since the intake shutter valve 6 is closed, and since the amount of fuel supplied to the cylinders is increased by the amount TAU21, a lean air-fuel ratio exhaust gas having temperature higher than the normal temperature, and containing a relatively large amount of NO_2 generated by the oxidizing catalyst 5, flows into the DPF 7. Therefore, the carbon particles collected by the DPF 7 are burned by NO_2 in the exhaust gas, i.e., the DPF 7 is regenerated. Further, NO generated by the combustion of carbon particles is absorbed by the NO_X absorbent 9.

On the other hand, if ANOX = 1 at step 205 in Fig. 2, i.e., if the conditions for regenerating the NO_X absorbent 9, as well as the conditions for regenerating the DPF 7, are satisfied, the routine executes step 215 to calculate the additional fuel injection amount TAU22 based on the engine speed and the accelerator signal in the manner similar to that in step 207. However, in this case, the value of TAU22 is determined so that the air-fuel ratio of the exhaust gas becomes a predetermined rich value (for example, an air-fuel ratio of about 13). After calculating the required additional fuel injection amount TAU22, the actual value of the additional fuel injection amount TAU2 is set to TAU22 at step 217 and, thereby, the air-fuel ratio of the exhaust gas discharged from the cylinders becomes a predetermined rich value (about 13, in this embodiment). In this case, since the intake shutter valve 6 is closed, and since the amount of fuel supplied to the cylinders are largely increased, a rich air-fuel ratio exhaust gas having a higher temperature than that in the normal regenerating operation of the DPF 7, and containing a relatively large amount of HC and CO flows into the DPF 7 and NO_X absorbent 9. In this condition, since the amount of O_2 contained in the exhaust gas is very small, the regeneration of the DPF 7 is temporarily interrupted. However, in this condition, since the NO_X absorbent 9 is regenerated by this rich air-fuel ratio exhaust gas having a high temperature, sulfate as well as NO_X in the NO_X absorbent 9 is released from the absorbent. Thus, the NO_X absorbent 9 is completely regenerated, and the absorbing capability of the NO_X absorbent 9 is completely resumed.

If ADPF ≠ 1 at step 201 in Fig. 2, i.e., if the conditions for conducting regenerating operation are not satisfied, the routine executes step 211 to open the intake shutter valve 6 and to deactivate the electric heater 5a. Then, at step 213, it is determined whether the value of ANOX is set to 1. If ANOX = 1 at step 213, i.e., if the conditions for conducting the regenerating operation of the

NO_X absorbent 9 are satisfied while the conditions for conducting the regenerating operation of the DPF 7 are not satisfied, the value TAU22 is calculated at step 215, and the actual value of the additional fuel injection amount TAU2 is set to the calculated value TAU22 at step 217. In this case, since the intake shutter valve 6 is opened, and since the electric heater 5a is deactivated, a rich air-fuel ratio exhaust gas having a relatively low temperature flows into the DPF 7 and NO_X absorbent 9. Therefore, DPF 7 is not regenerated. Further, the NO_X absorbent 9 is partially regenerated, i.e., sulfate in the NO_X absorbent 9 is not released, although NO_X absorbed in the NO_X absorbent 9 is released and reduced.

If ANOX ≠ 1 at step 213 in Fig. 2, i.e., if both the conditions for conducting the regenerating operations of DPF 7 and the NO_X absorbent 9 are not satisfied, the actual value of the additional fuel injection amount TAU2 is set to 0 at step 219. Therefore, in this case, only the normal fuel injection during the compression cycle is conducted, and the air-fuel ratio of the exhaust gas becomes largely lean.

As explained above, in this embodiment, the following three kinds of regenerating operations are conducted by the control circuit 20. Namely, when only the conditions for conducting the regenerating operation of the DPF 7 are satisfied, the temperature of the exhaust gas is raised by the intake shutter valve 6 and the electric heater 5a, and the air-fuel ratio of the exhaust gas is decreased to a lean air-fuel ratio of about 20 by the additional fuel injection. Thus, only the DPF 7 is regenerated, and NO generated from the DPF 7 and NO_2 passing through the DPF 7 are absorbed by the NO_X absorbent 9 and removed from the exhaust gas.

When both the conditions for conducting the regenerating operations of the DPF 7 and NO_X absorbent 9 are satisfied, the temperature of the exhaust gas is further raised by the intake shutter valve 6 and by increasing the amount of the additional fuel injection, and the air-fuel ratio of the exhaust gas is further decreased (enriched) to a rich air-fuel ratio of about 13. Thus, the NO_X absorbent 9 is regenerated completely by a rich and high temperature exhaust gas and, thereby, sulfate absorbed in the NO_X absorbent 9 is released.

On the other hand, when only the conditions for conducting the regenerating operation of the NO_X absorbent 9 are satisfied, the air-fuel ratio of the exhaust gas is decreased to a rich air-fuel ratio of about 13 by the additional fuel injection while keeping the intake shutter valve 6 open. Therefore, a relatively low temperature exhaust gas of a rich air-fuel ratio flows into the NO_X absorbent 9, and NO_X in the absorbent is released and reduced. However, in this condition, sulfate in the NO_X absorbent 9 is not released from the absorbent.

Next, determination of the conditions for conducting the regenerating operations of the DPF 7 and NO_X absorbent 9 is explained. Fig. 3 is a flowchart illustrating a routine for determining the conditions for conducting

the regenerating operations. This routine is processed by the control circuit 20 at predetermined regular intervals. In this routine, the flags ADPF and ANOX are set to 1 when the respective conditions for conducting the regenerating operation are satisfied.

In Fig. 3, steps 301 through 307 are steps for setting the value of ADPF.

In this embodiment, a cumulative value of the amount of fuel supplied to the engine 1 is calculated, and regenerating operations of the DPF 7 is conducted when the cumulative value reaches predetermined value. It is considered that the amount of the carbon particles discharged from the engine is approximately proportional to the amount of fuel burned in the engine. Namely, the cumulative value of the fuel injection amount is considered to represents the amount of the carbon particles collected by the DPF 7. Therefore, in this embodiment, it is considered that the amount of carbon particles collected by the DPF 7 reaches a predetermined value when the cumulated value of the fuel injection amount reaches a predetermined value. Namely, when the cumulative value of the fuel injection amount reaches a predetermined value, the flag ADPF is set to 1 in order to conduct the regenerating operation of the DPF 7.

In Fig. 3, counters FD and FN are used as parameters which represent the cumulative value of the fuel injection amount. The values of the counters FD and FN are set by the routine in Fig. 4. The routine in Fig. 4 is processed by the control circuit 20 at a predetermined regular intervals, and increases the values of the counters FD and FN by the amount TAU (fuel injection amount in the normal operation of the engine) every time the routine is processed (steps 401 through 405 in Fig. 4). Therefore, the values of the counters FD and FN correspond to the cumulative value of the fuel injection amount TAU.

In Fig. 3, at step 301, it is determined whether the value of a counter FD exceeds a predetermined value FD_0. If FD > FD_0 at step 301, the value of the flag ADPF is kept at 1 for a predetermined time. Namely, if FD > FD_0 at step 301, the value of a counter TD is increased by 1 at step 307, and the value of the flag ADPF is kept at 1 until the value of the counter TD exceeds a predetermined value TD_0 at steps 309 and 313. When the value of the counter TD becomes larger than TD_0, the value of the counter FD is cleared at step 311, thereby, when the routine is next processed, steps 303 and 305 are executed to clear the value of the counter TD and to set the value of the flag ADPF to 0. Therefore, by executing steps 301 through 313, the regenerating operation of the DPF 7 in which the intake shutter valve 6 is closed and the additional fuel injection is performed is conducted by the routine in Fig. 2 for a predetermined time (TD_0) every time the cumulative value of the fuel injection amount reaches a predetermined value (FD_0).

The value FD_0 in step 301 is the amount of the carbon particles accumulated in the DPF 7 at which the regenerating operation should be conducted, and the

value TD_0 is the time required for the regenerating operation vary in accordance with type and size of DPF 7. It is preferable to determine the actual values of FD_0 and TD_0 by experiment using an actual DPF. In this embodiment, for example, FD_0 is set to a value corresponding to six liters of fuel, and TD_0 is set to a value corresponding to 180 seconds of time.

Steps 315 through 327 in Fig. 3 are steps for setting the value of the flag ANOX. In this embodiment, similarly to the flag ADPF, the flag ANOX is set to 1 when the cumulative value FN reaches a predetermined value FN_0, and is kept at 1 for a predetermined time TN_0 (steps 315 through 327).

The amount of NO_X generated by the engine 1 is considered proportional to the amount of fuel burned in the engine. Therefore, the amount of NO_X absorbed in the NO_X absorbent 9 is also considered proportional to the cumulative value of the fuel injection amount. Therefore, in this embodiment, similarly to the regenerating operation of the DPF 7, the regenerating operation of the NO_X absorbent 9 is conducted every time the cumulative value of the fuel injection amount reaches a predetermined value. In steps 315 through 327, FN and TN are counters similar to the counters FD and TD, respectively, and FN_0 and TN_0 are predetermined threshold values similar to FD_0 and TD_0, respectively. The actual values of FN and TN vary in accordance with type and size of NO_X absorbent 9, and are preferably determined by experiments using an actual NO_X absorbent. In this embodiment, for example, FN_0 is set to a value corresponding 0.2 liters of fuel, and TN_0 is set to a value corresponding to 0.5 seconds of time.

By executing steps 315 through 327, the regenerating operation of the NO_X absorbent 9 in which the amount of the fuel supplied to the engine is increased by the additional fuel injection is conducted by the routine in Fig. 2 for a predetermined time every time the amount of NO_X absorbed in the NO_X absorbent 9 reaches a predetermined value. Further, as explained in Fig. 2, the regenerating operation of the NO_X absorbent 9 is conducted when the flag ANOX is set to 1 even when the regenerating operation of the DPF 7 is being carried out. Therefore, when the regenerating operation of the DPF 7 is being conducted, the NO_X absorbent 9 is regenerated by the exhaust gas of higher temperature than that in the normal regenerating operation and, thereby, the NO_X absorbent 9 is regenerated completely.

Fig. 5 is a timing diagram of the regenerating operation of DPF 7 and the regenerating operation of the NO_X absorbent 9. Fig. 5 shows a case in which a diesel engine having a displacement of 2400 cubic centimeter is operated at a speed 2000 RPM and an output torque 80 newton-meter. In this case, assuming that FD_0 is six liters and that FN_0 is 0.2 liters, the regenerating operation of the DPF 7 is repeated at intervals of about 60 minutes, and the regenerating operation of the NO_X absorbent 9 is repeated at intervals of about 2 minutes as shown in Fig. 5.

Further, if the periods of the regenerating operations of the DPF 7 and NO_X absorbent 9 (TD_0 and TN_0) are set to about 3 minutes and 0.5 seconds, respectively, the regenerating operation of the NO_X absorbent 9 is always conducted once or twice during the regenerating operation of the DPF 7 as shown in Fig. 5. Therefore, by setting the timing of the regenerating operations of the DPF 7 and NO_X absorbent 9, the NO_X absorbent 9 is regenerated periodically by the exhaust gas having a temperature higher than that of the normal regenerating operation and, thereby, SO_3 (sulfate) as well as NO_X is released from the NO_X absorbent 9 periodically. Thus, the absorbing capacity of NO_X absorbent 9 can be maintained at a high level.

Though the additional fuel injection during the exhaust cycle is conducted during the regenerating operations in the above embodiment, the additional fuel may be supplied to the exhaust gas passage directly during the regenerating operations. In this case, an additional fuel injection valve is disposed in the exhaust gas passage upstream of the oxidizing catalyst 5, and the additional amount of fuel is injected into the exhaust gas passage upstream of the oxidizing catalyst 5.

Further, though the timing of the regenerating operations is determined by estimating the amount of the carbon particles accumulated in the DPF 7 and the amount of NO_X absorbed in the NO_X absorbent 9, the control of the regenerating operation can be simplified by conducting the regenerating operations at regular intervals regardless of the amount of carbon particles in the DPF 7 and the amount of NO_X in the NO_X absorbent 9.

Next, another embodiment of the present invention is explained with reference to Fig. 6. Fig. 6 is a drawing similar to Fig. 1 which illustrates another example of a device for conducting the method in the present invention. In Fig. 6, reference numerals same as those in Fig. 1 also designate same elements as those in Fig. 1. The device in Fig. 6 is different from the device in Fig. 1 in that an NO_X reducing catalyst 10 is disposed in the exhaust gas downstream of the DPF 7 instead of NO_X absorbent 9 in Fig. 1. The NO_X reducing catalyst 10 is a catalyst which is capable of reducing NO_X in the exhaust gas selectively even if the air-fuel ratio of the exhaust gas is lean. Namely, though NO in the exhaust gas is removed by collecting it by the NO_X absorbent 9 in the previous embodiment, NO in the exhaust gas is directly reduced by the NO_X reducing catalyst 10 in this embodiment.

The NO_X reducing catalyst 10 in this embodiment has a substrate made of, for example, zeolite ZSM-5, and metals such as copper Cu and iron Fe are attached to the substrate by an ion exchange method. Alternatively, a substrate made of zeolite such as mordenite and precious metal such as platinum Pt attached thereon can also be used as the NO_X reducing catalyst 10. The NO_X reducing catalyst 10 selectively reduces NO_X in the exhaust gas to N_2 when the air-fuel ratio of the exhaust gas is lean, by reacting HC and CO with NO_X

selectively. Namely, the NO_X reducing catalyst 10 traps HC and CO in the exhaust gas in the pores of the porous zeolite, and selectively reduces the NO_X in the exhaust gas using trapped HC and CO even if the air-fuel ratio of the exhaust gas flowing into the NO_X reducing catalyst 10 is lean.

Therefore, in this embodiment, NO_2 in the exhaust gas generated by the oxidizing reducing catalyst 10 and NO generated at DPF 7 during the regenerating operation is reduced effectively by the NO_X reducing catalyst 10 disposed in the exhaust gas downstream of the DPF 7. However, in order to reduce NO_X in the exhaust gas effectively, it is required that a proper amount of HC and CO are trapped in the NO_X reducing catalyst 10. The air-fuel ratio of the exhaust gas of a diesel engine is considerably lean in the normal operation, and only a very small amount of HC and CO are contained in the exhaust gas. Therefore, when the normal lean air-fuel ratio operation of the diesel engine continues for a certain period, HC and CO trapped in the NO_X reducing catalyst 10 are used up in reducing NO_X in the exhaust gas and, thereby, the ability of the NO_X reducing catalyst for reducing NO_X becomes low.

In order to prevent this problem, the air-fuel ratio of the exhaust gas is also lowered (enriched) periodically in this embodiment. Namely, the control circuit 20 performs routines similar to those in Figs. 2 through 4 also in this embodiment, and controls the air-fuel ratio of the exhaust gas to a rich air-fuel ratio by conducting the additional fuel injection during the exhaust cycle of each cylinder. Similarly to the previous embodiment, fuel injected during the exhaust cycle is oxidized by the oxidizing catalyst 5 and generates a relatively large amount of HC and CO in the exhaust gas. Therefore, a proper amount of HC and CO are accumulated (trapped) in the NO_X reducing catalyst 10, and NO_X in the exhaust gas is reduced by these HC and CO components when the normal operation of the engine is resumed. The routines processed by the control circuit 20 in this embodiment for conducting the regenerating operation of the DPF 7 and for accumulating HC and CO are substantially the same as the routines in Figs. 2 through 4. Therefore, a detailed explanation thereof are not repeated here.

As explained above, in the present invention, the diesel particulates from the diesel engine are collected by, for example, a DPF, and burned by NO_2 in the exhaust gas. Further, NO generated by the reaction between the carbon particles and NO_2 passing through the DPF 7 are removed from the exhaust gas by, for example, an NO_X absorbent or an NO_X reducing catalyst. Therefore, according to the present invention, the accumulated carbon particles can be easily removed from a DPF without increasing the amount of NO_X released to the atmosphere.

Claims

1. A method for purifying the exhaust gas of a diesel engine comprising:

a step for oxidizing nitrogen monoxide in the exhaust gas of a diesel engine into nitrogen dioxide, thereby forming nitrogen dioxide in the exhaust gas;
a step for collecting carbon particles contained in the exhaust gas;
a step for reacting nitrogen dioxide in the exhaust gas formed by oxidation of nitrogen monoxide with the collected carbon particles, thereby oxidizing the collected carbon particles by nitrogen dioxide in the exhaust gas and, at the same time, reducing nitrogen dioxide in exhaust gas to nitrogen monoxide; and
a step for removing nitrogen monoxide formed by the reaction between nitrogen dioxide and the collected carbon particles from the exhaust gas.

2. A method according to claim 1, wherein said step for removing nitrogen monoxide from the exhaust gas comprises a step for collecting nitrogen monoxide in the exhaust gas by contacting the exhaust gas with an absorbent capable of absorbing nitrogen monoxide in the exhaust gas.

3. A method according to claim 1, wherein said step for removing nitrogen monoxide from the exhaust gas comprises a step for reducing nitrogen monoxide, in the exhaust gas, to nitrogen.
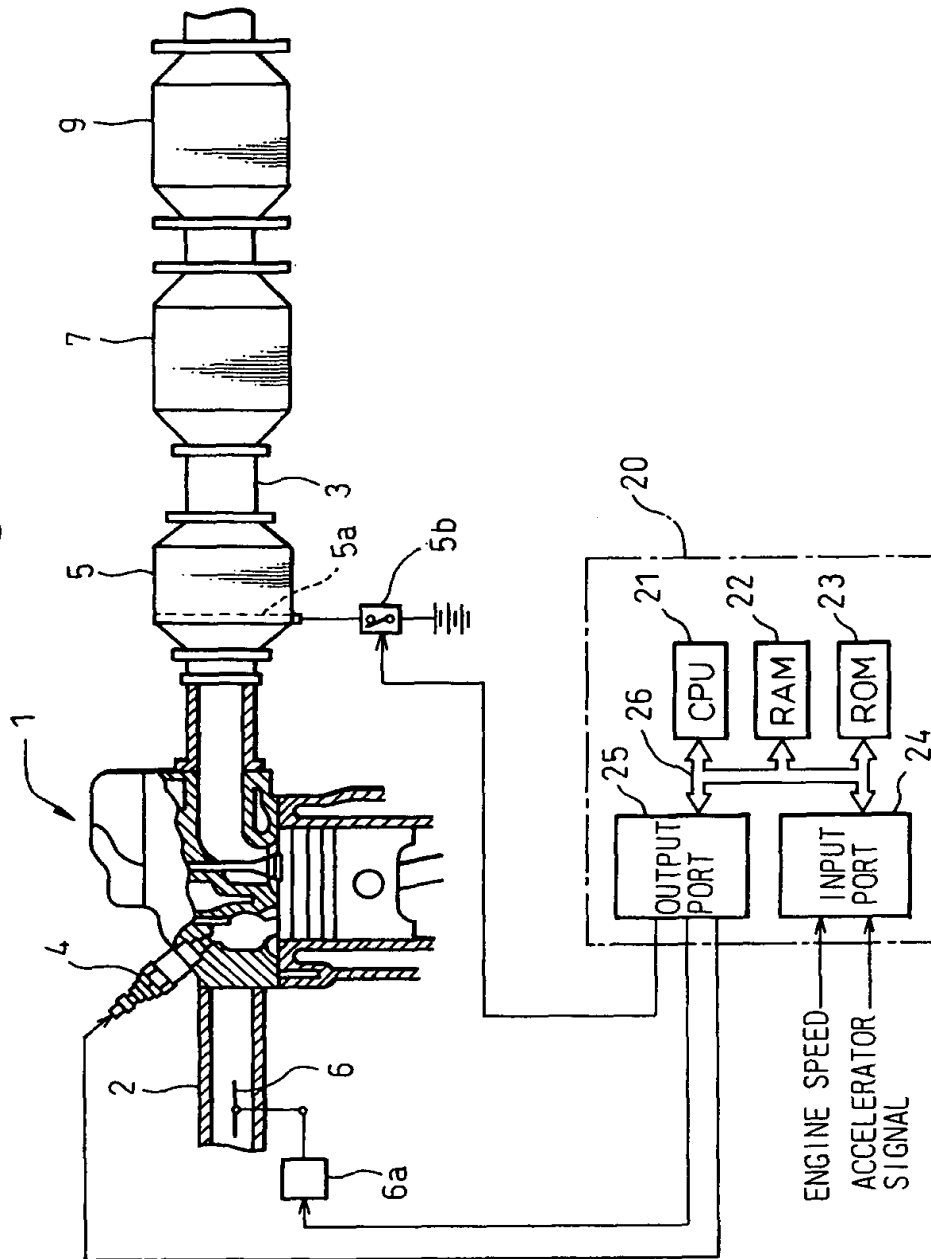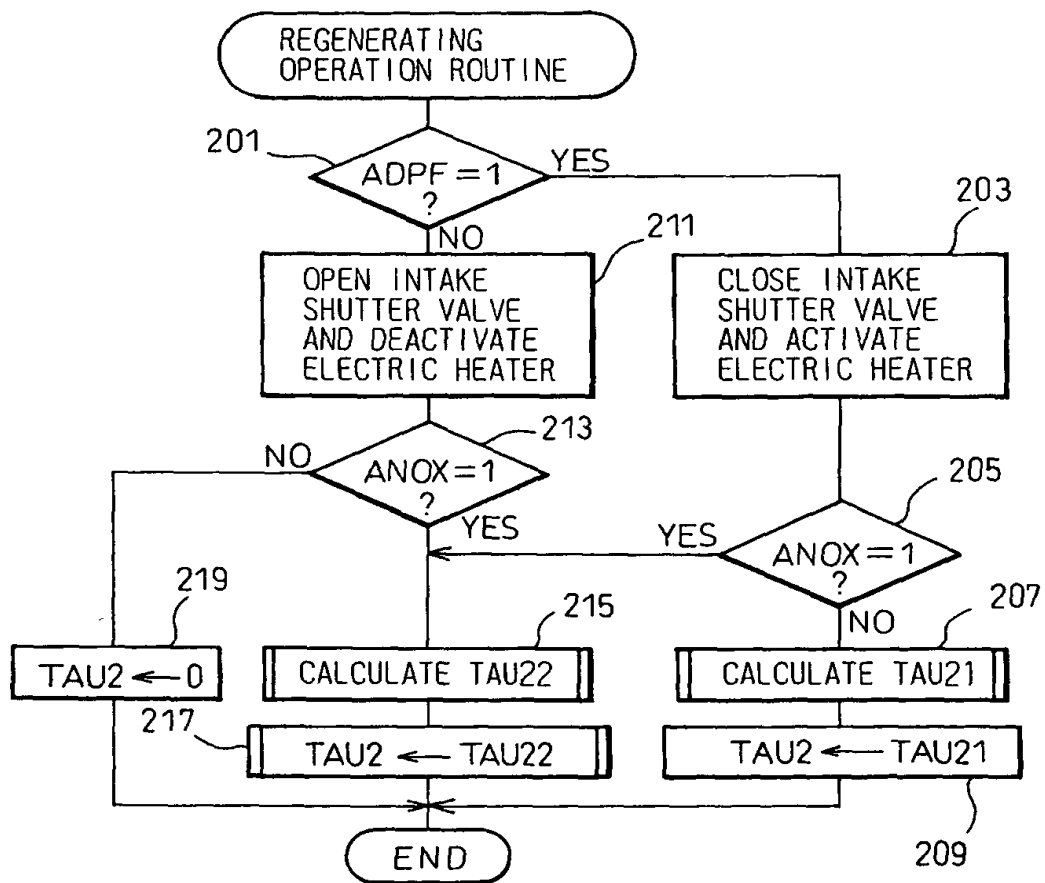
Fig.1

Fig.2

```
         ┌─────────────────────┐
         │   REGENERATING      │
         │ OPERATION ROUTINE   │
         └─────────────────────┘
                   │
     201           ▼                    YES
         ┌─────────────────┐────────────────────────┐
          ╲   ADPF = 1    ╱                          │
           ╲      ?      ╱                    203     │
            ╲──────────╱                             │
                │ NO              211                │
                ▼                                    ▼
        ┌──────────────────┐           ┌──────────────────┐
        │  OPEN INTAKE     │           │  CLOSE INTAKE    │
        │  SHUTTER VALVE   │           │  SHUTTER VALVE   │
        │  AND DEACTIVATE  │           │  AND ACTIVATE    │
        │  ELECTRIC HEATER │           │  ELECTRIC HEATER │
        └──────────────────┘           └──────────────────┘
                │         213                        │
    NO          ▼                                    │
  ┌─────────────────────┐                            │     205
  │      ╲ ANOX = 1 ╱                                ▼
  │       ╲    ?   ╱                          ╲  ANOX = 1 ╱
  │        ╲──────╱  YES         YES           ╲    ?    ╱
  │           │    ◄──────────────────────────  ╲───────╱
  │     219   │                                      │ NO      207
  │           ▼ 215                                  ▼
┌──────────┐ ┌─────────────────┐           ┌──────────────────┐
│ TAU2 ← 0 │ │ CALCULATE TAU22 │           │ CALCULATE TAU21  │
└──────────┘ └─────────────────┘           └──────────────────┘
  │    217    │                                      │
  │           ▼                                      ▼
  │     ┌─────────────────────┐         ┌──────────────────────┐
  │     │  TAU2 ← TAU22       │         │  TAU2 ← TAU21        │
  │     └─────────────────────┘         └──────────────────────┘
  │           │                                      │
  │           ▼                           209
  └────────►┌─────────┐
            │   END   │
            └─────────┘
```

Fig. 3

ROUTINE FOR DETERMINING
CONDITIONS FOR REGENERATION

301 $FD > FD_0$? — NO

307 $TD \rightarrow TD+1$

303 $TD \leftarrow 0$

309 $TD > TD_0$? — YES

305 $ADPF \leftarrow 0$

313 $ADPF \leftarrow 1$

311 $FD \leftarrow 0$

315 $FN > FN_0$? — NO

321 $TN \leftarrow TN+1$

317 $TN \leftarrow 0$

323 $TN > TN_0$? — YES

319 $ANOX \leftarrow 0$

327 $ANOX \leftarrow 1$

325 $FN \leftarrow 0$

END

Fig. 4

```
        ┌─────────────────────┐
        │  COUNTER SETTING    │
        │  ROUTINE            │
        └─────────────────────┘
                  │
        ┌─────────────────────┐  ___401
        │   CALCULATE TAU     │
        └─────────────────────┘
                  │
        ┌─────────────────────┐  ___403
        │   FD ◄── FD+TAU     │
        └─────────────────────┘
                  │
        ┌─────────────────────┐  ___405
        │   FN ◄── FN+TAU     │
        └─────────────────────┘
                  │
        ┌─────────────────────┐
        │        END          │
        └─────────────────────┘
```

Fig.5

Fig.6
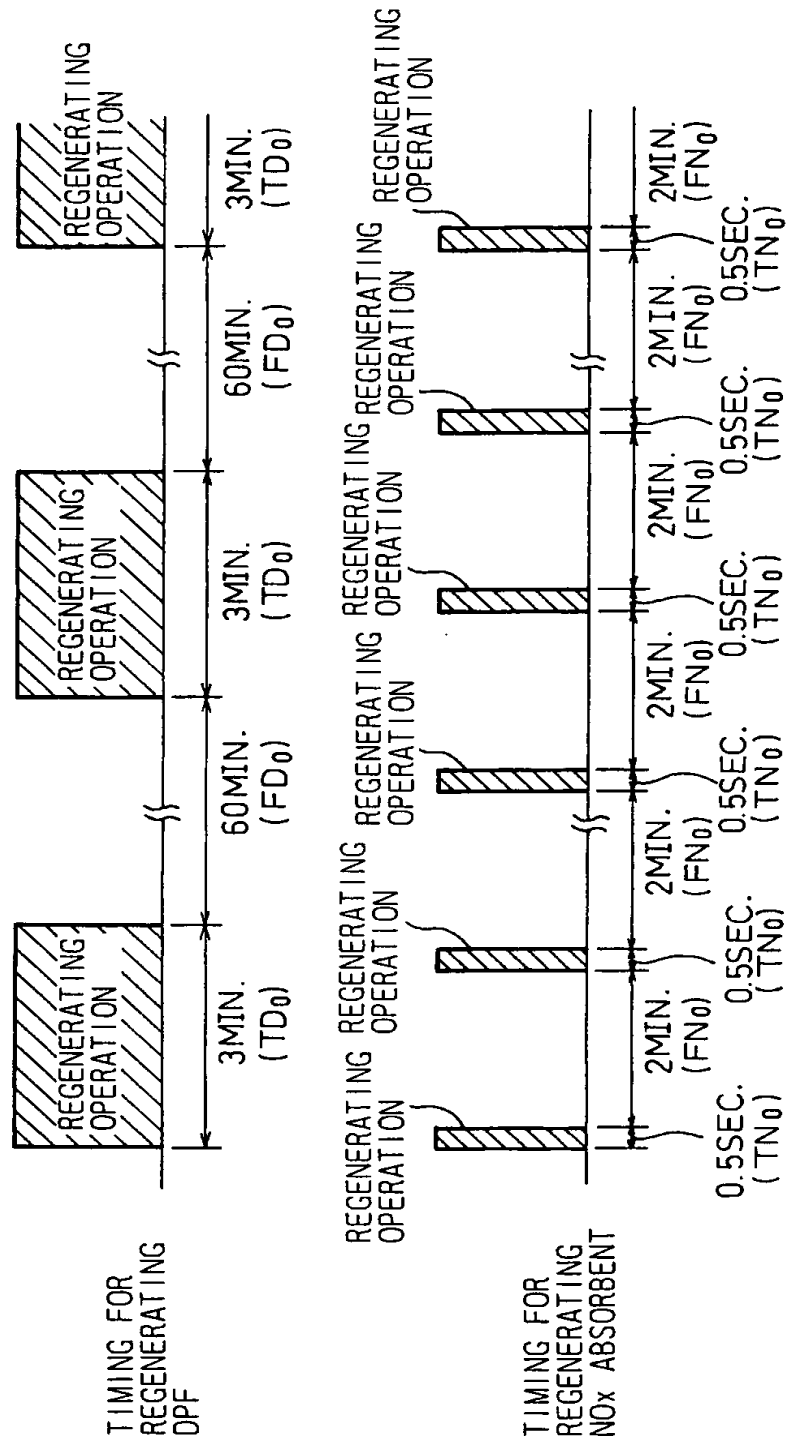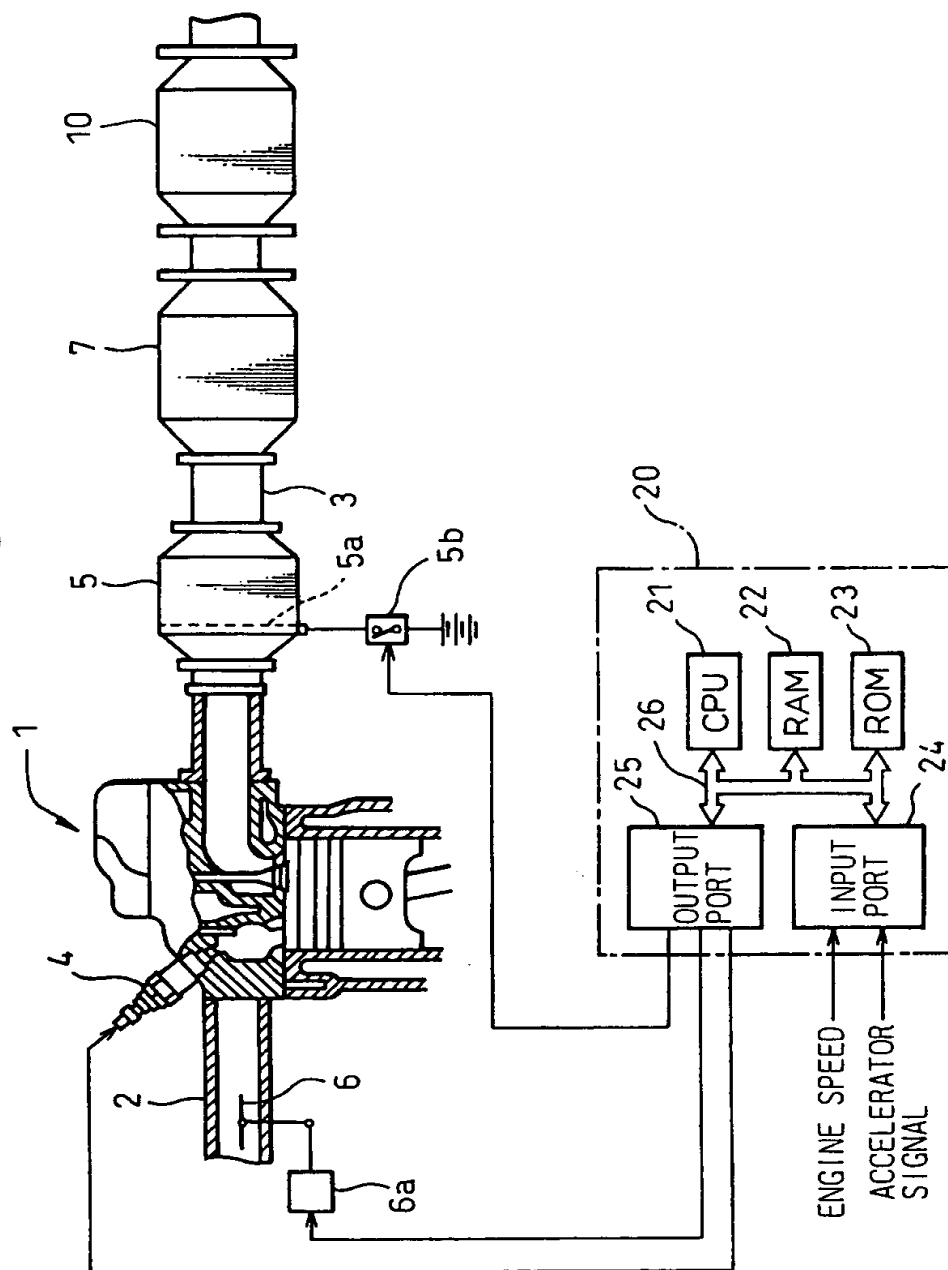

ENGINE SPEED

ACCELERATOR
SIGNAL

European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 11 2309

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,Y	EP-A-0 341 832 (JOHNSON MATTHEY INC) 15 November 1989 * page 2, line 43 - page 3, line 39; figure 1 * ---	1-3	F01N3/02 F01N3/08 F01N3/28
Y	PATENT ABSTRACTS OF JAPAN vol. 95, no. 005 & JP-A-07 139342 (TOYOTA MOTOR CORP), 30 May 1995, * abstract * ---	1,2	
Y	PATENT ABSTRACTS OF JAPAN vol. 015, no. 329 (M-1149), 21 August 1991 & JP-A-03 124909 (MITSUBISHI MOTORS CORP), 28 May 1991, * abstract * ---	3	
A	WO-A-95 18292 (VOLVO AB) 6 July 1995 * page 6, line 13 - page 7, line 23; figure 2 * ---	1,3	
A	US-A-4 270 936 (MANN GAMDUR S) 2 June 1981 * column 3, line 21 - column 4, line 4; figure 1 * ---		**TECHNICAL FIELDS SEARCHED** (Int.Cl.6) F01N
A	PATENT ABSTRACTS OF JAPAN vol. 018, no. 491 (M-1672), 13 September 1994 & JP-A-06 159037 (TOYOTA MOTOR CORP), 7 June 1994, * abstract * -----		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 October 1996	Torle, E